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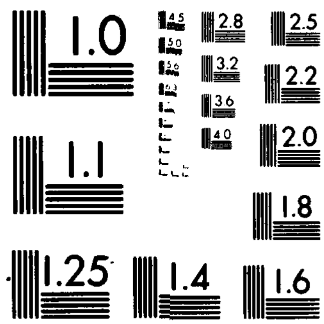

MICROCOPY RESOLUTION TEST CHART

NPRDC TR 80-21

April 1980

COMPUTER-ASSISTED LITERACY INSTRUCTION IN PHONICS

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 14 NPRDC-TR-80-21	2. GOVT ACCESSION NO. AD-A084269	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 COMPUTER-ASSISTED LITERACY INSTRUCTION IN PHONICS		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 Robert A. Wisher		8. CONTRACT OR GRANT NUMBER(s) 16 F63522
9. PERFORMING ORGANIZATION NAME AND ADDRESS Navy Personnel Research and Development Center San Diego, California 92152		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62763N 17 ZF63-522-001-011-03.01
11. CONTROLLING OFFICE NAME AND ADDRESS Navy Personnel Research and Development Center San Diego, California 92152		12. REPORT DATE 11 April 1980
		13. NUMBER OF PAGES 24 12 26
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Computer-assisted instruction (CAI)
Academic Remedial Training (ART) Program
Reading instruction
Literacy instruction
Reading grade level
Remedial training
Automated instruction
Phonics

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Twenty-four volunteers from the Academic Remedial Training (ART) Program at the Naval Training Center (NTC), San Diego, were given computer-assisted instruction (CAI) in phonics in place of the program's usual classroom instruction. The volunteers, native English-speaking recruits with reading grade levels (RGLs) below 4.5, as measured on the Gates-MacGinitie reading test and poor word attack skills, as measured by the Wide Range Achievement Test (WRAT), Level II, were removed from

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the classroom for the first week of the ART Program and given phonics instruction on a computerized multimedia system (MMS). The MMS, which includes a minicomputer, viewing consoles, response-entry keyboards, and a voice synthesizer, allowed the students (1) to see and hear the words they were to pronouce, (2) to request that the synthesizer repronounce words, and (3) to sound out words in isolation and in Navy-relevant text. A control group of 24 students with comparable reading scores participated in the normal NTC classroom instruction in phonics.

Both CAI and classroom instruction took place each morning for 3 hours over 5 successive days. Upon completion of the phonics course, both groups continued with the remaining 3 weeks of the ART Program, which covered vocabulary development, reading comprehension, and study skills. The RGLs of both groups were remeasured immediately after phonics instruction (WRAT) and at the end of the ART Program (Gates-MacGinitie test), and their RGL gains were compared to assess the instructional efficiency of the CAI course.

The CAI and control groups gained 1.3 and 1.0 RGL respectively on the WRAT and 2.4 and 2.5 RGL respectively on the Gates-MacGinitie tests. Thus, the students in the computer-assisted course did as well in phonics and in the remainder of the program as students who received classroom instruction. Although changes in the curriculum and delivery system would probably lead to improvements in student performance, no further work will be done on the phonics course until the other segments of the ART Program are computerized and evaluated.

FOREWORD

This research and development was conducted within Exploratory Development Work Unit ZF63-522-001-011-03.01 (Language Skills: Assessment and Enhancement) under the sponsorship of the Chief of Naval Education and Training. This report, which describes the automated teaching of English language phonics, is the first in a series that will assess the technological feasibility of automating literacy instruction. Subsequent reports will examine the feasibility of automating vocabulary, reading comprehension, and study skills instruction, and will include appropriate cost analyses.

The programming and technical assistance provided by Robert Pokorny and Leroy Fundingsland of the San Diego State University Foundation during development and testing, and the cooperation of the Academic Remedial Training Program, Recruit Training Center, San Diego, during the data collection phase, are appreciated.

Richard C. Sorenson

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Director of Programs

SUMMARY

Problem

The Navy currently accepts small numbers of marginally qualified recruits and uses uniformed instructors to teach them basic skills--predominantly reading. If manpower shortages force a lowering of enlistment standards, special programs such as the Academic Remedial Training (ART) program can be expanded to accommodate greater numbers of poorly qualified recruits. Doing so, however, will divert instructors from their regular assignments unless some or all of the remedial instruction can be automated.

Purpose

The purpose of this research and development effort was to examine the feasibility of teaching the phonics segment of the ART program by computer-driven voice synthesizer. The criterion for feasibility was that the computer-assisted course produce ART graduates who read as well as students who receive a comparable amount of classroom phonics instruction.

Approach

Twenty-four students from the ART program at the Naval Training Center, San Diego, were given phonics instruction on a multimedia system (MMS) that included a minicomputer, viewing consoles, response-entry keyboards, and a voice synthesizer. The MMS enabled the students (1) to see and hear the words they were to pronounce, (2) to request that the synthesizer repronounce words, and (3) to sound out words in isolation and in Navy-relevant text. A comparable classroom group served as a control.

Results

The students in the computer-assisted course did as well as those in the control group, but no better. Each group improved by over 1 reading grade level on the Wide Range Achievement Test. When the students taught by computer returned to the classroom for the remaining 3 weeks of the ART program, they performed as well as the controls.

Conclusions

Since student performance during computer instruction matched that measured in the classroom, the phonics segment of the ART program is a candidate for automation. Modification of the curriculum and computer system would probably improve student performance.

Future Plans

No further work will be done on the phonics course until the other segments of the ART program (vocabulary development, reading comprehension, and study skills) have been computerized and evaluated. Subsequent NAVPERSRANDCEN efforts will include appropriate cost analyses and, rather than attempting to match the performance of conventionally trained students in a fixed time frame, will attempt to reduce training time without reducing student performance. The segments that can be taught efficiently will be candidates for eventual implementation.

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INTRODUCTION

Problem

Studies by the Congressional Budget Office (1977) and others (e.g., Borack & Govindan, 1978) suggest that the military services' prime enlistment pool (i.e., male high school graduates, aged 18 to 21 years, in the higher mental categories) will decrease significantly during the next 20 years. Consequently, the Navy may be forced to accept more recruits from the lower mental categories. Past experience has demonstrated that these personnel are less useful in the service and attrite more frequently than do personnel in the higher mental categories.

The Navy currently accepts small numbers of marginally qualified recruits and uses uniformed instructors to teach them basic skills--predominantly reading. Support for reading instruction has varied directly with declines in the quality of the enlistment pool, mobilization, and responses to special programs such as Project 100,000 (Fletcher, Duffy, & Curran, 1977). As an outgrowth of Project 100,000 (1966-1972), a 4-week Academic Remedial Training (ART) program was established at the three Navy Recruit Training Centers. In 1978, nearly 3000 recruits completed ART. The typical ART student entered the program with a reading grade level (RGL) just above the fourth grade and achieved a two-grade gain in RGL before graduating. Hoiberg, Hysham, and Berry (1974) found that the exit RGL of ART graduates was the most important predictor of successful completion of the first year of Navy service.

If manpower shortages force a lowering of enlistment standards, remedial programs like ART can be expanded to accommodate larger numbers of poorly qualified recruits. Doing so, however, will divert instructors from their regular assignments. Costs for instructors will rise, and the investment the Navy has made in developing the occupational skills of its instructors will be lost while they are teaching literacy skills--a job for which they have little formal preparation. If the Navy must accept less qualified enlistees, it requires some other method of teaching basic skills.

Purpose

The purpose of this study was to examine the feasibility of teaching the phonics segment of the ART program by computer-driven voice synthesizer. The criterion for feasibility was that the course produce ART graduates who read as well as students who receive a comparable amount of classroom instruction.

Background

Approaches to Reading Instruction

Designing a remedial reading program for adults is quite different from establishing a beginning reading program for children, all of whom more or less start from "square one." Adults are often burdened by previous failures in learning to read. For them, the problem is to unlearn bad reading habits and acquire good ones.

Skilled reading can be taught to adults as a single, holistic process (Smith, 1971), or as a set of discrete subskills (Samuels, 1976). Proponents of the holistic view argue that reading is a rapid process in which readers comprehend by reducing uncertainty. They predict the meaning of text, and then sample additional text to confirm or reject those predictions. If they reject the predictions, they modify them according to the information

sampled. Some investigators, considering this process, have dubbed reading a "psycholinguistic guessing game" (Goodman, 1970). They hold that for skilled readers, who focus on meaning, subskills (e.g., letter-sound correspondences, decoding, word identification, and phrase recognition) become integrated and automatic. Since skilled readers process words and phrases as units, the holistic theorists argue, beginning readers should do likewise--even if they can manage only a few words and phrases. In their view, beginning readers should be taught to mimic skilled readers and concentrate on meaning.

Advocates of the subskills approach believe that unskilled readers must first master a hierarchy of subskills before they can integrate them. They contend that poor readers become bogged down in one subskill (e.g., decoding) and fail to comprehend what they are reading. (This is not to say that good decoding guarantees comprehension, but rather that inefficient decoding always interferes with comprehension.) Consequently, they assert, beginning readers should be taught initially to recognize a limited number of words and phrases with which to master subskills. The subskills should be taught independently, and, in time, integrated. Integration is the key--teaching only the subskills is not enough. The subskills must be practiced until they operate with little conscious attention, and become integrated into skilled reading.

Unfortunately, more is known about how to teach subskills separately than how they can be integrated. The present project incorporated both the holistic and subskills methods. Subskills were stressed in the early stages of the instruction, which dealt with words in isolation; holistic reading of Navy-relevant material was emphasized in the later stages.

Computer-Assisted Instruction (CAI) and Reading

The recent work in CAI and reading has been reviewed by Mason and Blanchard (1979). Two major efforts in these areas, both of which used children as subjects, are relevant to the present study: the Stanford project (Atkinson, 1968; 1974), and the Illinois project (Obertino, 1974; Riskin & Webber, 1974). Despite early hopes for a teacher-independent machine, investigators in both projects recommended a division of labor between machine and stand-up instructor, since neither was efficient by itself. The computer can facilitate individualized self-study, but it cannot lead a discussion or answer spoken questions. This is largely due to the metaphorical nature of language and to what Abelson and Reich (1969) call the pragmatic aspect--moving from literal decoding to plausible implication. Such learning activities demand a more intelligent instructional device, since the computer's ability to "comprehend" natural language is severely limited.

The bulk of reading instruction can, however, be delivered on a CAI system. Sound-letter correspondences, orthographic patterns, reading speed, word derivation and meaning, and, perhaps, literal comprehension fit into the programmed approach, especially with the tireless drill-and-practice power of the computer. Even the integration of reading subskills appears to be a promising application for CAI. On the other hand, some processes indicative of fluent reading, such as the use of syntactic and semantic redundancy to arrive at meaning and comprehension through inference, do not easily lend themselves to a purely CAI approach.

Much of the current Navy ART program, which includes instruction in phonic or decoding skills, vocabulary development, comprehension, reading rate, and study skills, qualifies for CAI delivery. The task of decoding or "sounding out" words is particularly difficult for many ART entrants, and the first week of the remedial program concentrates on phonics because it is fundamental to the other subskills. Since phonics deals with sounds, auditory communication is essential.

Audio Delivery Methods

Three methods of audio delivery are available to the CAI author: digitizing speech, random accessing of prerecorded material, and voice synthesis. The Stanford project used digitized speech; the Illinois project, random access; and the present study, voice synthesis. In order to explain the advantages of a voice synthesizer, all three methods will be described here.

The digitized speech technology used at Stanford required the analog-to-digital conversion of a spoken message into a pattern of bits. From a real-time sampling rate of 120,000 bits per second, 1 second of speech was compressed into 36,000 bits. For playback, an approximation to the original speech pattern was reconstructed from this compressed pattern. Disadvantages to this approach are the time and hardware required to digitize a word or message, the additional memory required to store a sizeable directory of words (each word requires about 10,000 bits), and the sophisticated software and floating-point hardware needed for the decomposition and reconstruction routines.

In the Illinois reading project (Yeager, 1976), a pneumatically driven, mylar, floppy disc was used to permit random access to human voice recordings within 500 milliseconds. This method had the following disadvantages:

1. Once the words were stored on the disc, it was difficult to change them.

2. There were problems with maintaining a consistent voice level (pitch and volume) when words were serialized to form a sentence.

3. Since the storage capacity of the disc was limited to a maximum of 20 minutes of recorded materials, students had to change discs during some lessons.

4. The pneumatically driven unit created an annoying background noise.

5. Unlike the Stanford project, in which the software addressed the audio dictionary by the word itself, the Illinois software required three parameters (track, sector, and length) for retrieval, with corresponding programming inconveniences.

The present study used a voice synthesizer, which offers several advantages over other computerized techniques. For example, it requires no additional hardware modules, since it communicates with the computer via an industry-standard serial interface, and its dictionary can reside in a smaller memory space. For these reasons, voice synthesis seemed to be a suitable approach to automating phonics instruction. A Votrax synthesizer was chosen because of its availability, even though it ranked lowest in a study of voice synthesizer intelligibility conducted by Laddaga and Sanders (1977).

APPROACH

Twenty-four volunteers from the ART program at NTC, San Diego, were given a 15-hour CAI phonics course in place of conventional classroom instruction. The students, native English-speaking recruits with reading grade levels (RGLs) below 4.5, as measured on the Gates-MacGinitie reading test, and poor word attack skills, as measured by the Wide Range Achievement Test (WRAT), Level II (Jastak & Jastak, 1965), were given phonics instruction on the multimedia system (MMS) located at NTC. A control group of 24 recruits with comparable RGLs participated in the normal ART classroom instruction in phonics.

The two groups were given both CAI and classroom instruction each morning for 3 hours over 5 successive days. The afternoons were devoted to military instruction and a library period when the students could read at their leisure. Upon completion of the phonics course, both groups continued with the remaining 3 weeks of the ART program, which covered vocabulary development, reading comprehension, and study skills. The RGLs of both groups, which had been measured before the students were admitted to the ART program, were remeasured immediately after phonics instruction (WRAT) and at the end of the ART program (Gates-MacGinitie test) and their RGL gains were compared to assess the instructional efficiency of the CAI course. Details of this approach follow.

Multimedia Delivery

CAI instruction was delivered using the MMS. This system, depicted in Figure 1, is controlled by a Digital Equipment Corporation PDP-11/70 minicomputer with 96K words of main memory and 80 million bytes of storage on a single disc drive. It includes a Votrax Model VS-6 voice synthesizer, a cartridge-loading International Video Corporation Model VCR 200 video tape recorder/player, a Sony color monitor with a 12-inch Trinitron tube, a black-and-white monitor, and a response-entry keyboard. The voice synthesizer, which was the critical component used in this effort, is a solid state unit designed to mimic 63 phonemes, each of which can be programmed with four inflection levels. Three other mechanisms, which are not programmable, control speech rates, audio level, and pitch. For this course, words pre-encoded and stored on the PDP-11/70 disc were pronounced by the synthesizer and simultaneously displayed on the monitors to clarify ambiguous phonemes--for example, to distinguish "b" from "v" or "d." Words were pre-encoded to make the synthesizer's output more intelligible. They could have been input to a software routine that, using a series of orthophonological "rules" of the English language, output an approximation of the word. This approach would have used less of the disc memory, since significantly more memory is needed to store words than sets of rules, and it would have saved the time spent encoding words.[1] Because spoken English often violates its rules, however, rule-dependent routines can cause the synthesizer to mispronounce words. Consequently, the additional time and memory required by this approach seemed well invested in return for clearer pronunciations.

Curriculum

The CAI course included instruction in reading words in isolation and in Navy-relevant text. First, the students were presented with groups of words and required to sound out various pronunciations until they recognized the correct one. These exercises, which emphasized decoding skills, including left-to-right visual processing of letters, letter-sound knowledge, and sound blending, were based on a subskills approach to reading instruction. No attempt was made to go beyond the skill of decoding, nor was decoding integrated with comprehension. Later in each day's instruction, however, the students participated in Computer-Assisted Reading (CAR) exercises that required them to comprehend text, and this portion of the course emphasized a holistic approach to reading. Initially, the students spent approximately 75 percent of the morning sessions on

[1]A pre-encoded word generally occupies about 250 bits of memory. The time required to encode a word varies with its complexity, but the average experienced programmer can encode about 25 words per hour. Root words already encoded can be combined to form more complex words (e.g., "base" and "ball"). Thus far, a dictionary of more than 8700 words has been encoded and stored on the PDP-11/70 disc. Routines are available that allow words to be added, deleted, or changed.

decoding exercises, and 25 percent in CAR instruction. The percentage of time given to CAR increased daily, however, and by the fifth day of instruction these proportions were reversed.

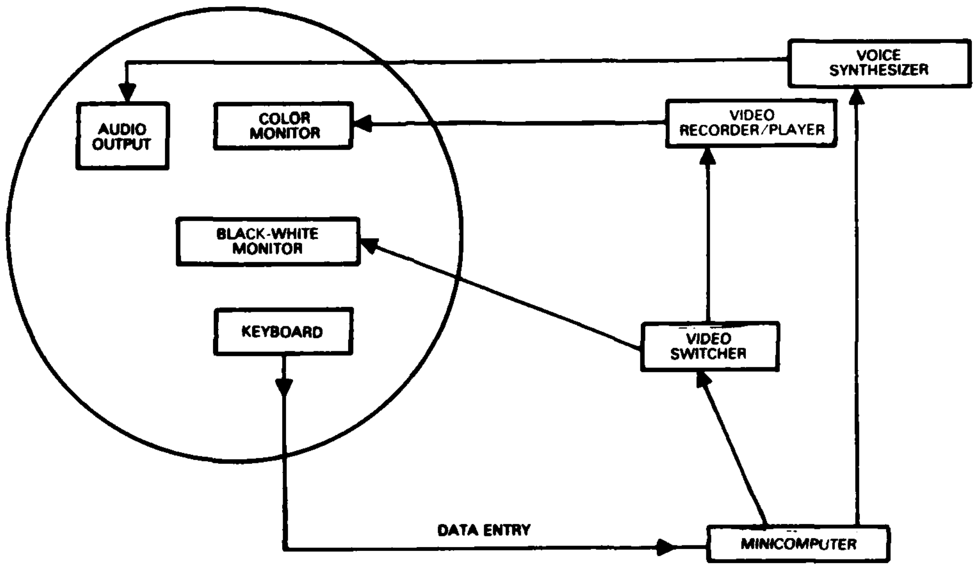

Figure 1. The multimedia system.

Experience gained in the ART program suggested that the course should not focus on basic letter and sound identification but on more advanced phonics principles, including variations in vowel sounds, vowel blends, consonant blends, and silent letter combinations. Consequently, the decoding exercises began with a summary of the distinction between long and short vowel sounds, using, for the most part, one- or two-syllable words. Table 1 lists the topics that were covered and indicates the instructional units dedicated to each. By going from the easier to the more difficult discriminations in letter-sound correspondence, these exercises built the recruits' confidence while improving their decoding skills. The students were given some rules to use in decoding words, but they were not required to memorize them, for three reasons:

1. Many of the most common words in English do not fit into a set of easily applied rules.

2. There is little evidence that rule learning is effective in developing word-attack skills, or that the student actually applies these rules outside the classroom (Weaver, 1978).

3. Competent decoders are usually able to sound out words effectively without being able to verbalize the rules they used for decoding.

Table 1

Decoding Exercises

Day	Topics	Units
1	Vowel Sounds	6
2	Vowel Blends	5
3	R Blends	4
4	Silent Letters Word Endings Word Beginnings	5
5	Synonyms Antonyms Homonyms Homophones	2

Course Design

The 22 units of decoding exercises listed in Table 1 were presented to the student as shown in Figure 2. Each unit began with a video-taped lecture that outlined the types of sounds to be drilled. For example, the lecture on vowel blends that sound as a long E, as in the word BE, presented each possibility along with a code word, as shown below:

Blend	Code Word
ea	beach
ee	agree
ei	receive
ey	key
ie	believe

The TV lecturer reviewed each of these blends with its code word. These same code words later appeared as the headings of display groups. Wherever possible, the lecturer reviewed appropriate phonic rules or generalizations. Each lecture lasted about 2 minutes.

Following the lecture, the computer transferred a working set of approximately 30 words from the dictionary of pre-encoded words and began to display them on the monitors until eight words--a limit set by the need for large character size and ample separation between words--filled the screen. Figure 3 presents an example of a display group. Following the appearance of each word on the screen and a brief pause that permitted the student to attack the word with his growing decoding skills, the synthesizer pronounced the word correctly. After the synthesizer had pronounced the word, the student could type its number to request that the synthesizer repeat it or he could hit the "return" key to request the next word in the group. If the student did not request repronunciation or a new word within 10 seconds, the voice synthesizer prompted him to "please respond." When the student was satisified that he had mastered all of the words in

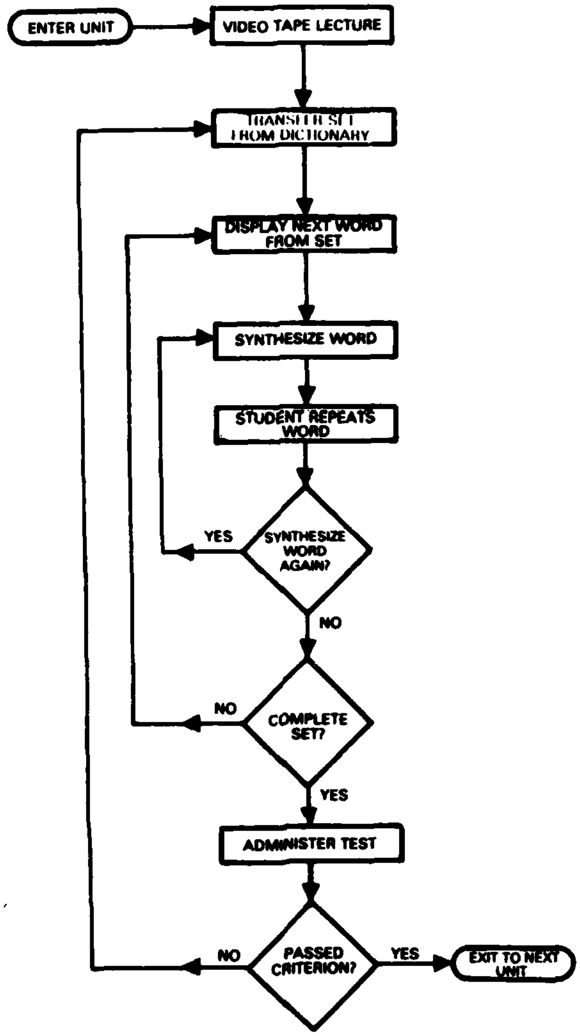

Figure 2. Diagram of an Instructional Unit.

LONG E -- BE

1. DETAIL	5. DELAY
2. REPAIR	6. ENOUGH
3. BEGIN	7. PREFIX
4. DECAY	8. REGION

TO HEAR ANY WORD, TYPE ITS NUMBER;
TO CONTINUE, HIT RETURN

Figure 3. Example of a display group.

a display group, he could hit the "return" key to instruct the computer to begin a new display group. Generally, three or four display groups were required to present all of the words in a working set.

The computer monitored student progress by a series of on-line tests, which assumed one of two formats: odd-out and mark. An example of the odd-out quiz is shown in Figure 4. Here four words were presented, one of which has a different target sound than the others. The target sound within each test word is underlined. The student selected the "odd" or different sound by pressing the number key that corresponded to the word with the "odd" sound. If he answered correctly on his first attempt, he received 20 points. If he answered incorrectly, the synthesizer uttered "Incorrect, try again," and the student made a second choice; 10 points were awarded for a correct second try, and 5 points for the third try. After the student entered the correct response, the synthesizer pronounced each of the four test words. The student could have the test words repronounced before proceeding to the next quiz.

'E' Sounds   Odd-Out

1. HELLO
2. SHE
3. LISTEN
4. WEST

Correct +20
SHE does not have a short E sound

Figure 4. Example of odd-out quiz.

In the mark quiz, words were tested individually. An example of this test format is presented in Figure 5. Again the target sound within each test word is underlined. Depending on the instructional unit, the student "marked" the underlined letters as having a long-vowel or short-vowel sound by pressing the letter L or S; or as having or not having a specified sound, such as the "ur" sound as in "fur," by pressing the letter Y (yes) or N (no). The computer awarded 5 points for correct answers. For incorrect answers, it pronounced the word immediately, crossed out the entered answer, and awarded 0 points. After the student completed this mark quiz, he could have any word repronounced by pressing the appropriate key.

The student encountered both quiz formats in each instructional unit and could earn a maximum of 100 points. He needed a score of 70 or greater, the current ART standard, to pass. If he failed to receive a passing score, he was required to view the lecture again, work through the exercises with a new word set, and take a test on a different set of items. If he failed a second time, he repeated this sequence until he got a passing score. After the third repetition, he was working with words and test items he had seen previously.

Words	Answer	Points
DETOUR	Long	+5
PROBLEMS	Short	+5
LEVEL	Short	+5
HE	Long	+5
RECOUNT	XXXX	Long
INTEREST	Short	+5
TAKEN	XXXX	Short
LESS	Short	+5
	Total for quiz = 30	

Figure 5. Example of mark quiz.

Figure 6, which summarizes the first day's decoding exercises, illustrates how this portion of the course was organized.

Day	Topic	Units	Display Sets	Tests
1	Vowel	A	Long A Short A	Odd-Out Mark
	Sounds	E	Long E Short E	Odd-Out Mark
		I	Long I Short I	Odd-Out Mark
		O	Long O Short O	Odd-Out Mark
		U	Long U Short U	Odd-Out Mark
		Y	Silent Long E Long I Short I	Mark Mark Mark Mark

Figure 6. Summary of first day's decoding exercises.

For the Computer-Assisted Reading (CAR) instruction, the student was presented with Chapters 17 and 18 from the Basic Military Requirements manual and was required to read the text silently from individual sentences displayed on the computer terminal. The CAR routine displayed a single sentence, such as the example presented in Figure 7, in which words considered as difficult are underlined. When the student pressed the number corresponding to an underlined word, the voice synthesizer pronounced the word selected. For example, it pronounced "administrative" when the student pressed button 2. The voice synthesizer pronounced each word as many times as the student wished, and presented the next sentence when the student pressed the "return" key.

Many Navymen, unfortunately (1), seem to know little about administrative (2) details (3) that affect their service (4) lives, or of education (5) opportunities (6) available (7) to them, or even of information (8) contained (9) in their service record.

Figure 7. Sample sentence from computer-assisted reading.

The system recorded the number of times the student requested pronunciation and computed his reading speed per sentence. A total of 450 sentences were available, with an average of four words per sentence that could be pronounced.

In order to ensure that a student was attempting to understand the text, a multiple-choice comprehension question appeared periodically on literal information in a recently displayed sentence. If the student selected the correct answer, he continued with the reading task; if he did not, the system redisplayed the sentence in which the quizzed information appeared, thus displaying the contextual source of the answer.

The main advantages of CAR instruction over a comparable classroom exercise are efficiency of feedback and unobtrusive monitoring of student reading progress. The monitored data were reading speed and pronunciation requests per sentence. In computing reading speed, adjustments were made for the response time required to request and pronounce a word.

Classroom Instruction

The control group used a phonics work booklet that contained a series of rules for the syllabication and pronunciation of words. These rules guided the student in first dividing a word into its vowel units and then marking whether each vowel was long or short. Students had to memorize these rules and demonstrate their proficiency in rule application by correctly dividing and marking an extensive series of real words and nonsense letter patterns. The classroom course was delivered in a lock-step manner, with about 12 students per instructor.

Experimental Procedures

Upon entry into the ART program, prospective candidates were introduced to the multimedia system, and given the opportunity to volunteer for the CAI course. Ninety-six percent of the candidates volunteered. Because only two MMS stations were available, the CAI group was run in pairs over a 3-month period.

The computer system accommodated from 2 to 10 other users during the phonics instruction. Consequently, although this study was given a high priority for central processor time, there were delays of up to 5 seconds in text display and feedback. This occurred less than 10 percent of the time when user demand was very high.

Evaluation

The students were evaluated in two phases. In order to measure the immediate impact of the phonics instruction, the Wide Range Achievement Test (WRAT), Level II, was administered to each group before the first day and following the final day of instruction. This test requires the student to pronounce a list of words graded for difficulty. No feedback was given during the test. When 10 successive words were mispronounced, testing stopped. None of the words used in WRAT appeared in the CAI curriculum.

Upon entry into and exit from the ART program, every recruit's comprehension skills were measured on alternate forms of the Gates-MacGinitie reading test. The results of this test were used to determine what effect the CAI instruction had when trainees returned to the classroom for the remainder of the ART program. If the CAI group performed as well as the control group throughout the ART instruction, then the automated phonics instruction could be substituted for the classroom version with no sequencing problems.

RESULTS

1. Figure 8, which depicts the results from the WRAT, shows that both the CAI and control groups improved by nearly the same margin--1.3 and 1.0 RGLs respectively. Although this improvement is significant for each group ($p < .05$ by a sign test), there was no significant difference between their pre-post difference scores ($p > .1$ by a t-test). The CAI instruction in phonics, then, was as effective as a comparable amount of lock-step classroom training.

2. The results of the Gates-MacGinitie reading test are plotted in Figure 9. Again, the CAI and control groups improved by nearly the same margin--2.4 and 2.5 RGLs respectively. The improvement is significant within groups ($p < .05$ for each group by a sign test), but there is no difference between groups ($p > .1$ by a t-test of pre-post difference scores). Again, the results indicate that the CAI delivery was as effective as the classroom version, but no better.

3. Since only the experimental group participated in the computer-assisted reading (CAR) exercises, its performance cannot be compared to that of a control group. Nevertheless, it is interesting to review these data in order to examine trends in reading improvement across days of CAI instruction. Although 450 sentences were available on the system, only one student completed the entire set. All students, however, did complete at least the first 150 sentences, which were divided into 5 blocks of 30 sentences each. As shown in Figure 10, the students' average reading rate per sentence

improved sharply between the first and second blocks and continued to improve, though less rapidly, thereafter. The big improvement at the beginning can be attributed in part to the students having adapted (1) to reading the sentences on the viewing consoles and (2) to the context of the chapter. The frequency of pronunciation requests decreased across days of instruction, dropping from nearly 60 percent on the first day to less than 20 percent on the final day.

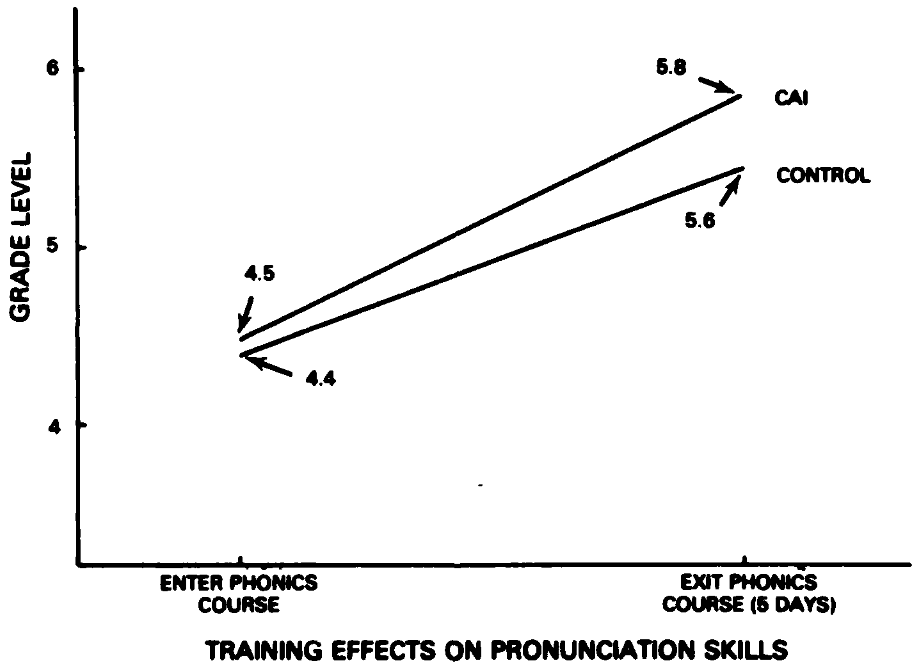

Figure 8. WRAT pre- and post-instruction tests.

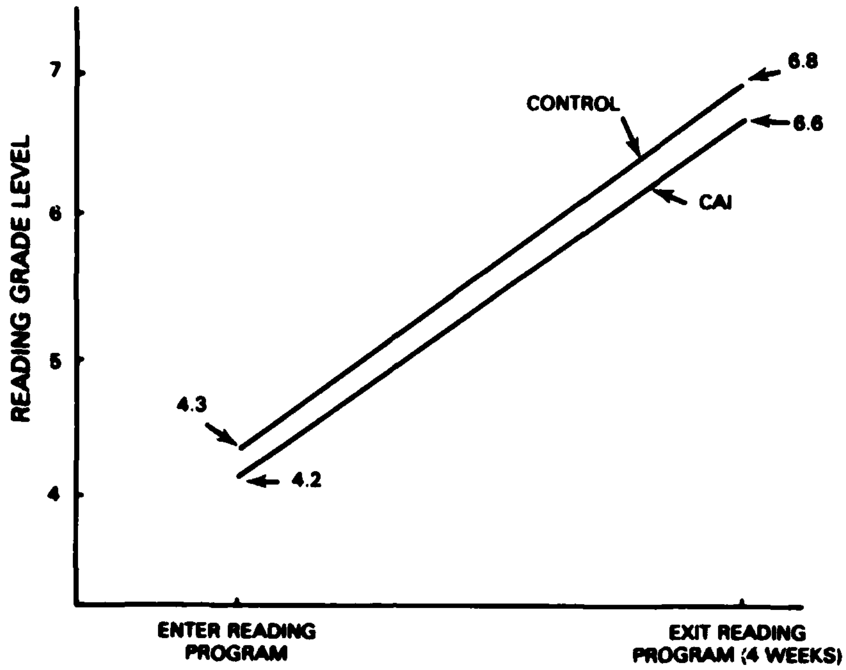

Figure 9. Gates-MacGinitie pre- and post-instruction tests.

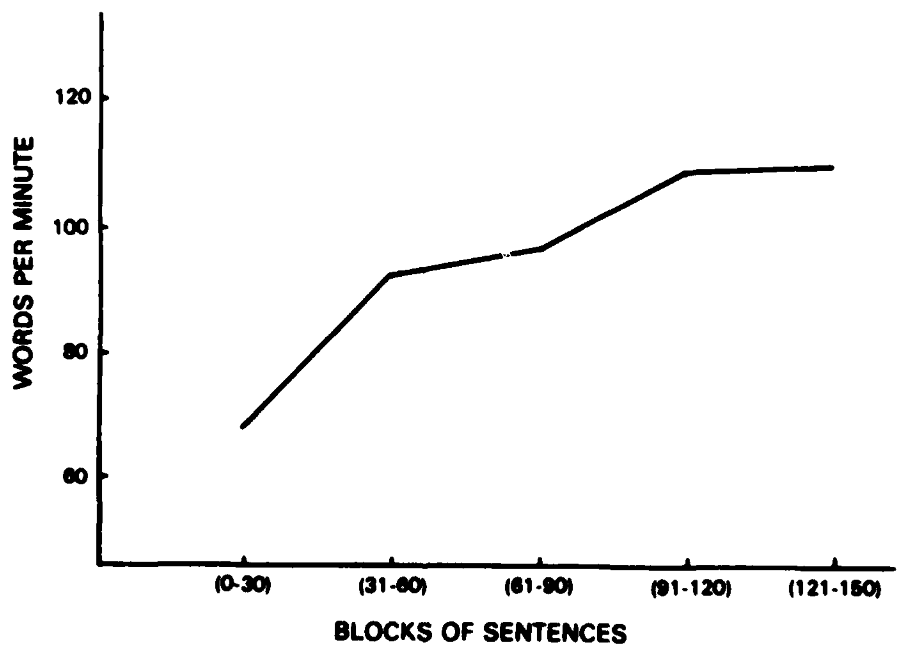

Figure 10. Computer-assisted reading.

CONCLUSIONS

1. Since performance during computer delivery matched that of the classroom, the phonics segment of the ART program is a candidate for automation. The performance of students in this course could probably be improved by the following modifications:

a. Improvements in the CAI curriculum could make the course less time-consuming, and lead eventually to an improvement in performance as well. For example, the reduction of words in an instructional unit could save student time with no reduction in performance.

b. A more intelligent CAI system could analyze the words that a student requested for pronunciation during the CAR routine to determine commonalities, such as a preponderance of words with a certain vowel blend, and give the student additional instruction by increasing the number of drill words with that vowel blend. In this way, the program could make real-time instructional decisions based on previous student interactions.

2. The voice synthesizer was applied successfully. Its hardware was extremely reliable and did not fail during the course. Although its intelligibility was not as good as that of other audio techniques, such as digitized speech and voice recording, it was adequate. Simultaneous oral and visual presentation seems crucial in using the synthesizer in a remedial program. In training programs that use a limited and easily distinguishable vocabulary such as the program for air traffic control communications, the synthesizer alone would probably suffice.

3. The CAI delivery probably fatigued the students, who were required to use the system for 3 consecutive hours, with breaks totaling only 20 minutes. Because so much instruction was delivered, students appeared to be tiring after about 2 hours. If the computer is integrated into the reading curriculum, no more than two daily sessions, each lasting 2 hours at most, should be scheduled. Supplemental off-line instruction could be delivered in the classroom or in self-study, where the pace is more deliberate, in contrast to the intense and demanding nature of CAI.

FUTURE PLANS

No further work will be done on the phonics course until the other segments of the ART program have been computerized and evaluated. Subsequent NAVPERSRANDCEN efforts will include appropriate cost analyses. The segments that can be taught most efficiently will be the strongest candidates for eventual implementation.

The vocabulary segment will be examined next. Rather than attempting to match the performance of conventionally trained students in a fixed time frame as was done in the phonics research, the vocabulary research will attempt to reduce training time without reducing performance. The voice synthesizer will be used to pronounce words; and on-line translation of words into other languages, notably Spanish and Tagalog, will be available for nonnative English speakers, who constitute about 40 percent of the San Diego ART population. Some of the CAI students will learn new words in four-word groups based on shared semantic features, while others will learn new words in alphabetical order. These groups will be compared to each other to assess the extent to which semantic associations facilitate vocabulary building, and to a third group of students who receive classroom instruction in vocabulary building to assess the instructional efficiency of CAI.

Cost indices will be developed for CAI and conventional vocabulary instruction to determine the learning rate advantage that CAI must offer to become cost-effective. For example, the cost index of CAI (e.g., hardware acquisition + software costs + maintenance costs + support materials + overhead) will be compared to the cost index of an instructor (salary + support materials + overhead). If the cost index for CAI is, for instance, twice that of a classroom instructor, then (assuming that the instructor and the computer can teach the same number of students) the learning rate of CAI must be at least twice that of the classroom for CAI to be cost-effective.

Planning is also underway for research of CAI courses in reading comprehension and study skill, which may be combined and taught as a single course.

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